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The Tampico Bridge in Mexico

Le pont Tampico au Mexique

Die Tampicobrücke in Mexiko

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SUMMARY

The Tampico bridge in Mexico represents an innovative example of mixing concrete sections and orthotropic steel sections in cable-stayed bridge decks. This paper sets out the various advantages of this concept which will most likely be frequently used in future projects.

RÉSUMÉ

Le pont de Tampico au Mexique est un exemple original d'association des matériaux béton et acier orthotrope dans les tabliers de ponts haubanés. L'article présente les nombreux avantages de ce concept qui devrait devenir d'usage fréquent dans le futur.

ZUSAMMENFASSUNG

Die Tampicobrücke ist ein Beispiel für die neuartige Verwendung von Beton und orthotropen Stahlquerschnitten für Brückenträger bei Schrägseilbrücken. Der Beitrag zeigt die Vorteile dieses zukunftsträchtigen Konzeptes auf.

1. GENERAL DESCRIPTION OF THE PROJECT

1.1 Main characteristics : (see fig 1 to 3)

- Location : bridge across the Panuco river in Tampico City (Gulf of Mexico).
- Clearance of main span above water : 50m.
- Total length of the bridge, including approach viaducts : 1543m.
- Length of the cable-stayed section between expansion joints : 878m.
- Main span : 360m. Short side spans : 70m.

- Structure of the deck :
  . Orthotropic steel girder for a 293.50m long central section of the main span,
  . Prestressed concrete girder for the remaining sections of main span, and lateral short spans.

  This concept which is the purpose of this paper, will be discussed in further details.

- Deck width : 18.10m, providing four lanes of traffic.
- Pylon : inverted Y shaped, 123.50m high. Rigid deck / pylon connection.
- Suspension : semi-fan shaped axial suspension composed of 4*11 stay cables.
- Foundations : undercut concrete cylinders up to 60m deep (North pylon).

Comec established the basic design around 1980.
The bridge has been in use and carrying traffic since October 1988.

1.2 New Stay technology :

Apart from the innovative deck structure design, mention has to be made of unique cable stay technology which has been specifically developped for this project: (see ref [1]).

The stays are composed of 30 to 60 galvanized T15 strands, housed within a petroleum wax injected HDP duct. The stays were prefabricated on the deck before erection.
This technology provides a 3 barrier protection against corrosion.

Moreover, the wax injection also provides the stay strands with a high performance fatigue behaviour, and overall damping of the stay is increased.
No vibration of the stays has been observed.

Lastly, contrary to classical cement grouting, wax injection can be carried out before erection, under high quality control conditions, which brings about a reduction in the overall construction time.

1.3 Special tests and studies :

The following tests and design studies were performed :

- Fatigue tests on stay samples at Empa laboratory (Zurich-Switzerland).

- Wind tunnel non-stationary tests of deck section model at Onera (Paris-France) and mathematical study of aeroelastic stability of the bridge using these tests.

- Study of hurricane behavior of the bridge when in operation and under construction, using Sogelerg "RAFALES" software.

- Non-linear step by step analysis of the construction stages of the main span, using Civilsoft "SCANNER" software.

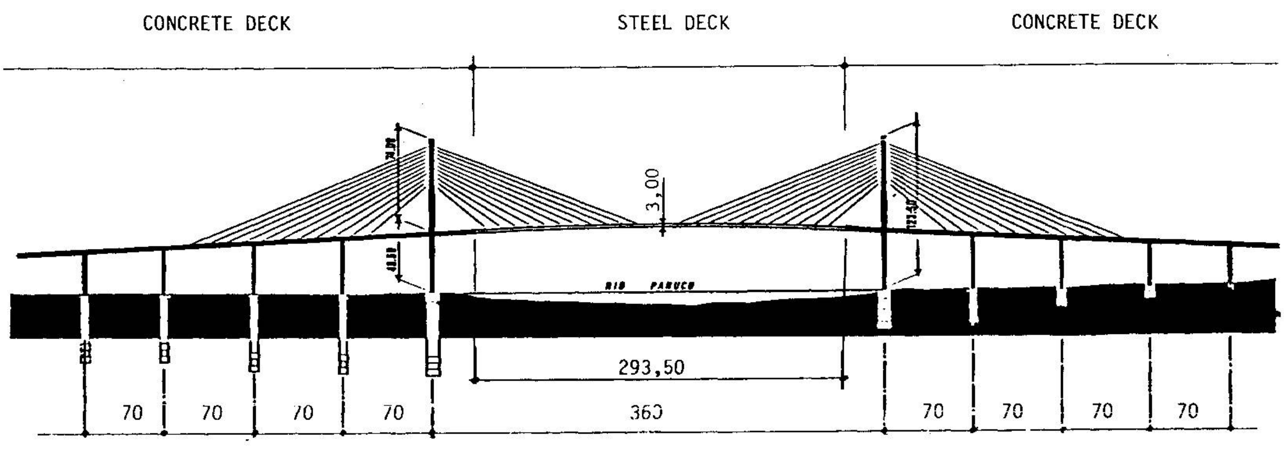

Fig. 1 Elevation of the Bridge

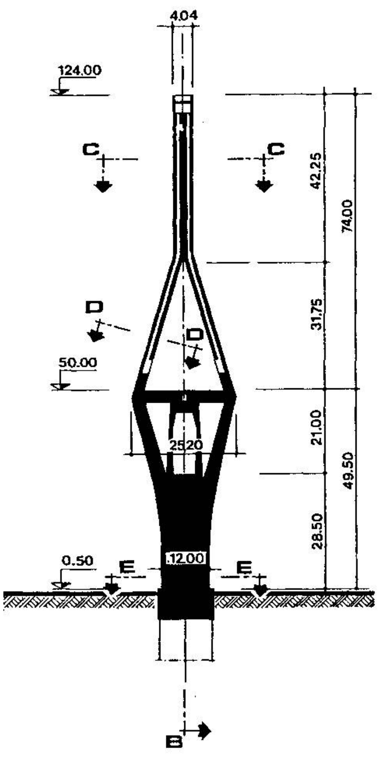

Fig. 2 - Elevation of the pylon

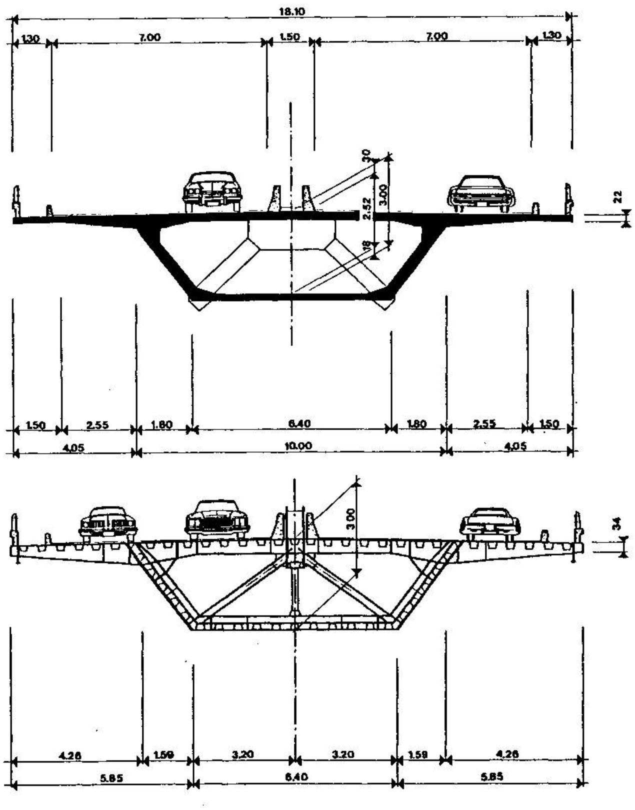

Fig. 3 Concrete and steel cross-sections of the deck

1.4 Construction of main span :

The length of the steel segments of the main span is 12m , which corresponds to the distance between stays. Due to the high risk of hurricane at the location of the bridge, it was finally decided to erect 24m long double segments in order to reduce the construction time of the main span.

These double segments, weighing 160 tons, produced large deflections of the flexible deck during its construction , so the above mentionned SCANNER non-linear analysis became nesessary, so as to ensure good geometrical control of the process, as well as an effective control of stresses in the structure during its construction.

The construction of the steel section of main the span was carried out within 4 months.

The facts confirmed our doubts, since the very powerfull hurricane "GILBERTO" passed within 100km of the bridge, only one month after the completion of the main span...!

2. BASIS OF THE MIXED DECK DESIGN OF THE TAMPICO BRIDGE. (see fig 1)

At an early stage of the project, the very poor soil conditions were considered.
For reasons of economy, it was decided to design the lateral deck short spans with a prestressed concrete girder, while using an orthotropic steel deck girder in the central part of main span.
This allowed both a drastic reduction of vertical forces on the pylons foundations, and a reduction in the cost of the imported steel for the stays.

The length of the main span concrete girder sections was set at 35m, which corresponds to half the length of the lateral spans. The construction of the whole of the concrete deck section was then carried out by the segmental cantilever method.

The external shapes of the concrete and steel deck cross-sections were designed to be compatible (see fig 3). These two sections are linked together using 60 12T13 prestressing tendons.

The following gives an overview of the benefits one can find from such mixed concrete/steel deck design.

3. ADVANTAGES OF THE CONCEPT FOR LARGE CABLE-STAYED BRIDGES.

Let us analyze the advantages of this structural design from the following points of view :

- Static equilibrium,
- Dynamic and wind behavior,
- Construction method,
- Cost.

3.1 Static equilibrium : (see fig 4).

Assuming steel being material 1 and concrete being material 2, we define :

- DW1 : lineal dead weight in orthotropic steel deck section,
- DW2 : lineal dead weight in concrete deck section,
- LL : lineal live load on main span

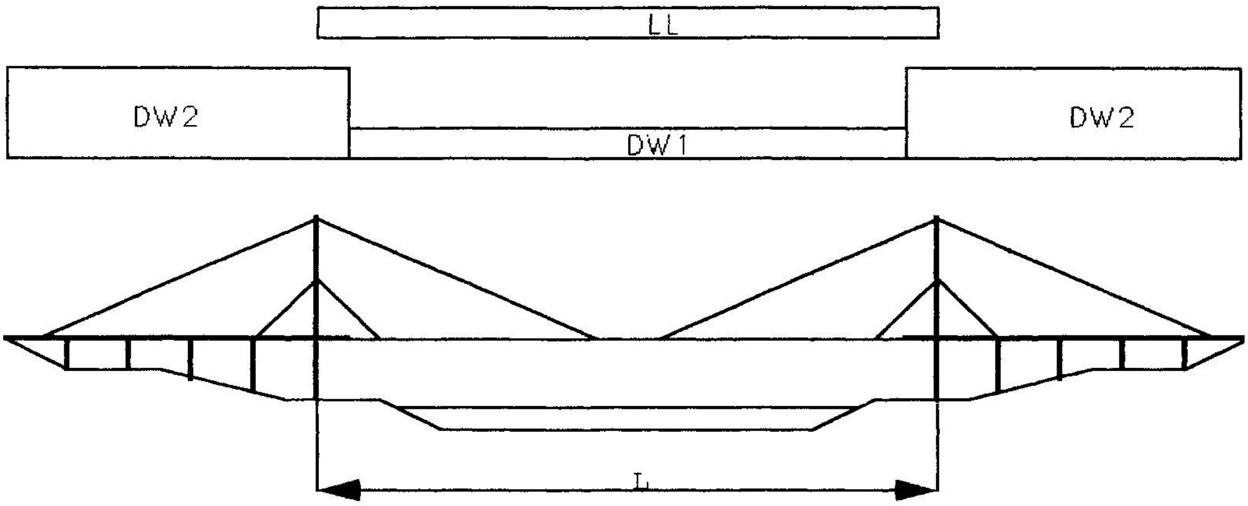

Fig 4 Static equilibrium of the bridge

- Positive contact of the deck on its side piers is ensured since :
DW2 > (DW1 + LL) (29.50 >> (11.50 + 4.78 = 16.28))

- Max vertical force on pylon is proportional to (DW1 + LL), so, in comparison with the case of concrete main span, it is reduced by (DW1 +LL)/(DW2 +LL) = 0.475 , and longitudinal compression of the deck is reduced by the same ratio.

3.2 Dynamic and wind behavior :

Compared to conventional cable-stayed bridges with long steel side spans , static and dynamic vertical deflections of the main span are reduced. Lateral deflections of the main span under wind effects are also significantly reduced for the bridge during construction and also when in service.

3.3 Construction method :

The concrete section of the deck by being built first, gives a permanent access during the construction of the central span.

3.4 Cost:

- This design allows the construction of the concrete side spans with the same advantageous economic conditions as for ordinary short concrete spans viaducts.
- In comparison with conventional cable-stayed bridges, the points mentioned in 3.2 and 3.3 above also provide savings on both material and construction costs.
- The cost of whole the suspension (pylon+stays), and foundations of the pylons is reduced proportionally to the (DW1 + LL)/(DW2 + LL) ratio.

4. MULTI-MIXED DECK STRUCTURE CONCEPT APPLIED TO LARGER SPANS.

A good economic criteria for main span, is actually based on the total **(suspension + deck)** cost per unit length of deck. For deck structure type i , this unit cost can be expressed as follows, versus abscissa x :

$$C_i = a*(DW_i + LL)*x + C_{di} \qquad \text{(case of Harp suspension)}$$

where a = constant value, depending upon the geometrical shape of the suspension, and on the cost of the stays per unit weight.
Cdi = cost of the deck per linear meter including construction costs.

The upper graphic of fig 5 shows the linear variation of C for 3 different deck structures,
for instance : i = 1 : prestressed concrete deck, i = 2 : composite concrete/steel deck,
i = 3 : orthotropic steel deck.
It is interesting to note that lighter deck structures have an higher Cdi deck cost, but a lower a* (DWi + LL) slope of their suspension cost.

From these 3 curves, the x1 and x2 limits of the economical area for every deck structure type, in a large multi-mixed deck span can be obtained. Note that the deck structure types with the best resistance to longitudinal compression are also, from an economic point of view, placed in the areas close to the pylon.

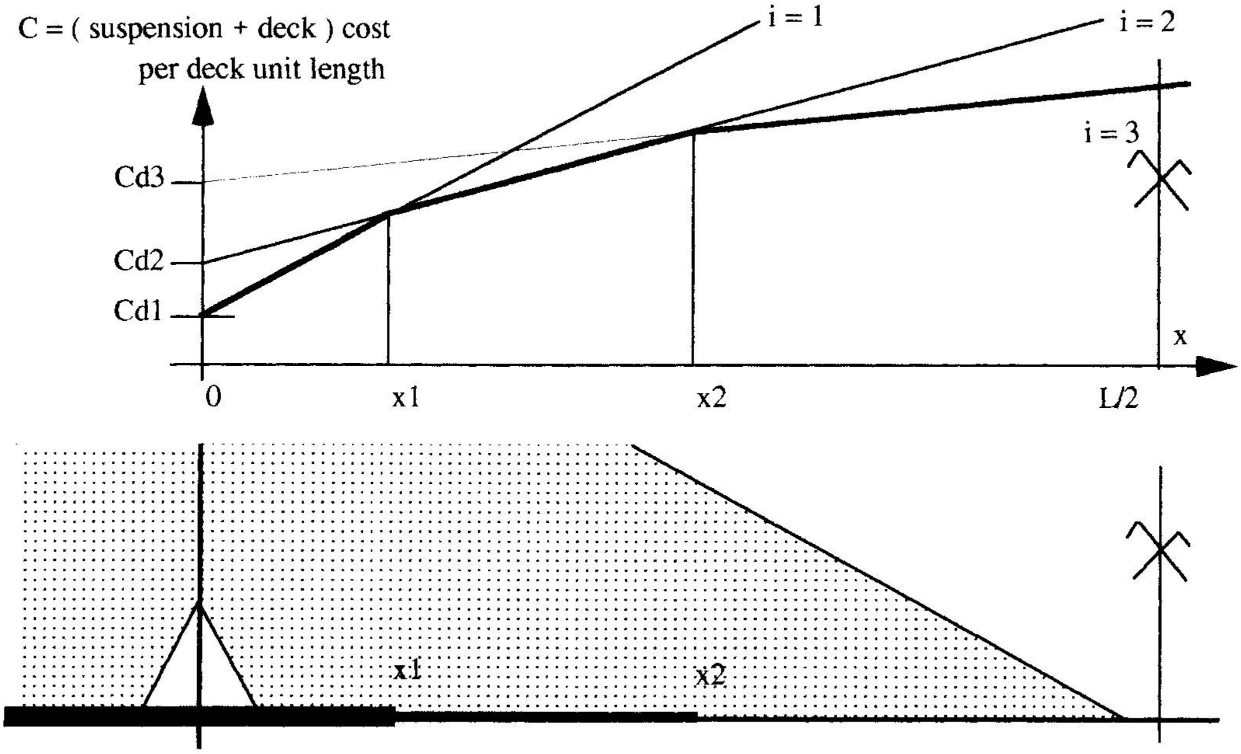

Fig 5 Multi-mixed deck structure for larger spans.

The above example which is a theoretical extension of the Tampico bridge concept would obviously need at least 1000m span to be of interest.

5 CONCLUSION :

We have presented the various innovative aspects of the Tampico bridge, in terms of stay-cables technology, construction process, and principally in terms of its original structural concept.
We sincerely hope that this second large cable-stayed bridge designed and built by Mexico, will greatly contribute to the development of cable-stayed bridges, generally.

Ref [1] : Alain CHAUVIN - Developments in the technology of bridge stays.
FIP Congress New Delhi, Feb 1986.